Obstetric Dimensions of the True Pelvis in a Medieval Population From Sudanese Nubia

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ABSTRACT Functional analysis of the true pelvis (defined as that portion lying below and including the pelvic brim) was undertaken on a sample of 36 females from the Medieval site of Kulubnarti in Sudanese Nubia. Standard obstetric measurements were taken and compared to four additional prehistoric skeletal samples and to modern American standards for the same obstetric dimensions. Relative to the other prehistoric populations, the Kulubnarti pelves are smaller in most dimensions and, when compared to modern American standards, from one-third to one-half would be diagnosed as contracted in one or more planes.

Given the meager, fluctuating resources of these Medieval Nubians’ harsh desert environment, pelvic size reduction is a likely result of body size reduction as one biological response to nutritional stress (Mittler and Van Gerven, 1989; Moore et al., 1986; Van Gerven et al., 1981). It is argued, however, that size reduction created a high potential for either maternal-neonatal morbidity and mortality due to fetopelvic disproportion or neonatal loss due to low birth weight. In either case, it is suggested that the Kulubnarti population paid a significant biological price for this aspect of size reduction.

Functional analysis has been an essential perspective of skeletal biology. The fact that form follows function provides the basis for understanding and interpreting much of the variation found in skeletal morphology. Because of this, complex skeletal features such as the human pelvis have been an important focus of investigation. The pelvis has been of particular interest to anthropologists because of its role in human bipedalism. However, in addition to studying the evolutionary response of the pelvis to bipedal striding, there has been a great deal of interest in how the female pelvis is able to accommodate upright posture and maintain enough space to allow for delivery of a viable term-size fetus.

The study of sexual dimorphism of the pelvis, however, has generated the greatest interest in functional skeletal morphology. Interestingly, a paradox becomes apparent when we evaluate how skeletal biologists have applied a functional paradigm to the study of sexual dimorphism. They have used obvious male-female differences such as the subpubic arch, subpubic angle, or sacrosciatic notch, each functionally related to obstetrics, to diagnose sex. Yet, they have generally failed to evaluate these features with respect to their functional-obstetric significance. This has been particularly true for the study of anatomically modern populations.

Several factors may have contributed to the lack of a functional approach to the ob-
stetric pelvis. First, such analysis requires articulation of the hip bones with the sacrum. The fragmentary nature of most archaeological remains often precludes this procedure. Second, interest in sexual dimorphism has focused more on sexual diagnosis than functional interpretation. Both factors are unfortunate given the importance of such variation to our understanding of growth and nutrition in the attainment of adult pelvic form as well as the impact of the adult female form on maternal and neonatal health.

For example, J. L. Angel (1975, 1978, 1982) argued that flattening of the pelvic inlet is a response to nutritional stress. Cook (1984) reported that low status Hopewell females from the lower Illinois Valley had flatter pelvic inlets than did higher status females. Cook argued that this may be direct evidence for nutritional stress.

Obstetric practitioners, working with living populations, have likewise associated nutritional deficiency with contracture of the pelvis (Baird, 1945, 1969; Thomas, 1947, 1956). The modern clinical focus, however, has not been on female pelvic morphology per se but on parturition and fetopelvic disproportion as these affect maternal-neonatal morbidity and mortality (Caldwell and Moloy, 1933; Friedman, 1978; Pritchard et al., 1985; Thoms, 1956; Thoms et al., 1939).

In this paper we analyze the obstetric dimensions of female pelves from an ancient Sudanese Nubian population. Our purpose is to determine the extent to which size reduction and contracture in the true pelvis had occurred and presented important reproductive challenges, 1) from the standpoint of obstetric difficulty, and 2) from the standpoint of neonatal size.

**MATERIALS AND METHODS**

**Sample selection**

Materials for the present study were excavated by one of us (D.V.G.) in 1979 at the Medieval site of Kulubnarti in Sudanese Nubia. The site is located some 80 miles south of Wadi Halfa in the Republic of Sudan. A total of 406 individuals were disinterred from two cemeteries spanning the current era from 550 to c. 1550.

Due to the desert climate of Sudanese Nubia, the preservation of both soft and skeletal tissues is exceptional. One female was discovered buried on a mat with a fetal skeletal in the breech position. It is reasonable to assume that her death resulted from prolonged obstructed labor.

All adult females (ages 19–44) with complete pelvic remains, lacking gross morphological abnormalities and without adhering soft tissues that would impede measurement, were included in the analysis (n = 36). Age at death was determined by observations of epiphysial union, morphology of the os pubis, dental wear, and degenerative changes of articular surfaces (Van Gerven et al., 1981). Mean age at death for the sample was 30.5 ± 6.9 years.

Of the 36 individuals analyzed, 10 were sexed positively on the basis of soft tissues (breasts and genitalia) and the remainder were sexed according to morphology of the pelvis, including sciatic notch morphology, elevation of the auricular surface, subpubic angle, pubic/ischial index, and presence of a pre-auricular sulcus. It should be noted that such estimation of sex is unlikely to confound the present analysis through an inadvertent inclusion of mis-sexed male pelves. Earlier analysis of both males and females of known sex produced non-overlapping male-female morphological distributions, and the individuals utilized in the present sample fall so well within the female pattern that the likelihood of misdiagnosis is remote.

**Procedures and instruments**

Anthropometric measurements were taken of each true obstetric pelvis, defined as that portion of the pelvis lying below and including the pelvic brim. This anatomical area has obstetric significance since it is the bony canal through which the fetus must pass during parturition. To facilitate description and analysis, the true pelvis was divided into three functional planes: the inlet, midpelvis, and the outlet.

The plane of the inlet is bounded anteriorly by the posterior superior margin of the pubic symphysis, laterally by the linea terminalis, and posteriorly by the promontory and alae of the sacrum (Oxorn and Foote,
The following inlet diameters were measured (Fig. 1):

a. anteroposterior (obstetric conjugate)—extending from the posterior superior margin of the pubic symphysis to the middle of the sacral promontory;

b. transverse—extending from the widest distance across the brim at the level of the iliopectineal line;

c. oblique—extending from each sacroiliac joint, right and left, to the corresponding iliopectineal eminence.

The plane of the midpelvis, which contains the narrowest obstetric dimension, is bounded anteriorly by the inferior border of the pubic symphysis, laterally by the ischial spines, and posteriorly by the sacrum at or near the junction of the fourth and fifth sacral vertebrae (Oxorn and Foote, 1980). The following diameters were measured (Fig. 2):

a. anteroposterior—extending from the lower border of the pubic symphysis to the junction of the fourth and fifth sacral vertebrae;
A. Anteroposterior view showing the anteroposterior and transverse diameters.

B. Sagittal section showing the anteroposterior diameter.

Fig. 2. Diameter measurements of the midpelvis.

b. transverse—extending from the tip of one ischial spine to the tip of the other;
c. posterior-sagittal—extending from the midpoint of the biischial spinous diameter to the junction of the fourth and fifth sacral vertebrae.

The outlet consists of two approximately triangular areas not in the same plane but sharing the bituberous diameter as a common base. Boundaries of the anterior triangle include the apex of the subpubic angle, the pubic rami, and the ischial tuberosities. The posterior triangle is bounded by the line of the sacrotuberous ligaments spanning the sacrosciatic notch and the sacrococcygeal joint (Oxorn and Foote, 1980). The subpubic angle as well as the following diameters were measured (Fig. 3):

a. anteroposterior—extending from the inferior margin of the pubic symphysis to the sacrococcygeal joint;
b. transverse—extending from the inner surface of one ischial tuberosity to the inner surface of the other.

Each pelvis was manually articulated and secured with an elastic band. Dimensions were taken to the nearest 0.1 mm using a Helios sliding caliper. Exceptions to this were the anteroposterior and posterior sagittal diameters of the midpelvis. These were taken to the nearest 0.5 mm using a ruler. The subpubic angle was measured with a protractor to the nearest degree. Following data collection, all linear measurements were converted to centimeters and rounded to the nearest 0.1 cm.

After measurement, all pelves were classified according to the system of Thoms et al. (1939), based on the relative lengths of the inlet diameters, as follows:
a. dolichopellic (long oval)—the anteroposterior diameter exceeds the transverse diameter.
b. mesatipellic (round)—the anteroposterior and transverse diameters are of equal length, or the former exceeds the latter by not more than 1 cm.
c. brachypellic (transverse oval)—the transverse diameter exceeds the anteroposterior diameter by more than 1 cm but less than 3 cm.
d. platypellic (flat)—the transverse diameter exceeds the anteroposterior diameter by 3 cm or more.

In addition, certain obstetrically important morphologic features, not associated with measurement, were observed. These included linearity of the pelvic sidewalls; breadth, curvature, and inclination of the sacrum; shape and breadth of the sacrosciatic notch; prominence of the ischial spines; and curvature of the pubic rami.

### Statistics

Age at death and dimensions of the pelvis were described in terms of means, standard deviations, and range values. In order to determine whether a differential size effect was operating within the sample, all pelvic dimensions were correlated with femur length. No correlations were significant at $P < 0.05$ and, therefore, no further attempt to statistically remove a body size effect was made. Comparison to other archaeological populations were made using Student’s t test.

### RESULTS

#### General description

From the standpoint of shape, 58% of the pelvises were classifiable as brachypellic (transverse oval), 28% mesatipellic (round), 11% dolichopellic (long oval), and 3% as platypellic (flat). Shape of the midpelvis is most often characterized by slightly convergent sidewalls (indicated by greater inlet than outlet transverse dimension) associated with well-rounded anterior and posterior segments; well-curved neutrally inclined sacra; and well-rounded and wide sacrosciatic notches associated with ischial spines of variable prominence. Shape of the outlet is characterized by curved pubic rami forming relatively narrow subpubic angles. Throughout, morphological features related to shape are typically female. The means, standard deviations and range values for all obstetric dimensions are shown in Table 1.

### Comparison of Kulubnarti with modern obstetric standards

In order to assess the Kulubnarti pelvises functionally, they were compared to modern American obstetric standards. This was particularly useful for dimensions that by clinical experience represent a pathological reduction or contracture based on average fetal cranial dimensions (Oxorn and Foote, 1980; Pritchard et al., 1985). It is evident from the data in Table 2 that the Kulubnarti pelvises are generally smaller than the American standards. Furthermore, at least 1/3 to 1/2 of the sample would be clinically diag-
TABLE 3. Kulubnarti pelves compared to North American Groups

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Kulubnarti</th>
<th>Indian Knoll</th>
<th>Pecos Pueblo</th>
<th>Libben</th>
<th>Haida</th>
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<tbody>
<tr>
<td><strong>Inlet</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Ant-Post.</td>
<td>$\overline{x}$</td>
<td>10.3</td>
<td>10.8$^*$</td>
<td>9.1$^*$</td>
<td>9.8</td>
</tr>
<tr>
<td>S.D.</td>
<td>0.8</td>
<td>0.7</td>
<td>0.8</td>
<td>0.8</td>
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<tr>
<td>N</td>
<td>36</td>
<td>28</td>
<td>42</td>
<td>11</td>
<td>15</td>
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<tr>
<td>Trans.</td>
<td>$\overline{x}$</td>
<td>11.6</td>
<td>13.4$^*$</td>
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<td>S.D.</td>
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<tr>
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<td><strong>Midplane</strong></td>
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<td>Ant. Post</td>
<td>$\overline{x}$</td>
<td>11.5</td>
<td>12.0$^*$</td>
<td>11.8</td>
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<td>S.D.</td>
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<td>4</td>
<td>6</td>
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<tr>
<td>Trans.</td>
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<td>9.1</td>
<td>11.2$^*$</td>
<td>9.9</td>
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<td>S.D.</td>
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<td>36</td>
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<tr>
<td>Post-Sag.</td>
<td>$\overline{x}$</td>
<td>4.3</td>
<td>4.8$^*$</td>
<td>4.2</td>
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<tr>
<td>S.D.</td>
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<tr>
<td><strong>Outlet</strong></td>
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<td>Ant-Post</td>
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<td>11.4$^*$</td>
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<td>30</td>
<td>45</td>
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<td>15</td>
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</table>

1 Amerindian data from R.G. Tague, 1986.

* Student's $t$ test comparison to Kulubnarti $P < 0.05$.

—, data not available.

Nosed as contracted in one or more planes. For example, 33% of the pelves have anteroposterior diameters of the inlet of <10.0 cm and 67% have transverse diameters of the inlet <12.0 cm. Midpelvic dimensions are likewise reduced, with 42% having bispinous diameters of <9.0 cm, 84% with posterior sagittal diameters of <4.5 cm, and 47% with combined bispinous and posterior sagittal diameters of <13.5 cm. Although 75% of the Kulubnarti pelves have subpubic angles of <90°, the obturator diameters are generally not reduced.

The pelves of three individuals (S-224, R-99, and R-85) are noteworthy because certain of their obstetric dimensions appear to be extremely reduced. Both S-224 and R-85 have anteroposterior diameters of the inlet of <9.0 cm and bispinous diameters of the midpelvis of <8.5 cm. R-85 also has a posterior sagittal diameter of <4.0 cm. The midpelvis of R-99 is even more markedly reduced with a bispinous diameter of 7.7 cm and posterior sagittal diameter of 3.1 cm. By modern clinical standards, all three of these individuals would have been at substantial obstetric risk with respect to delivery of a viable term-sized fetus. If the risk to these Nubian females was mitigated by the birth of a smaller neonate, the potential reproductive costs assume another form—those associated with low birth weight.

Comparison of Kulubnarti to archaeological Amerindian samples

There are surprisingly few comparative investigations of female pelves from archaeological samples. Tague (1986), however, has provided a detailed comparison of male and female pelves from samples taken from Indian Knoll, Pecos Pueblo, Libben, and Haida populations. In this landmark study, he focused on functional aspects of the obstetric pelvis in order to better understand the functional nature of sexual dimorphism. When Tague's data are compared to the American obstetric standards utilized in this study, the mean dimensions of these Amerindian pelves are also reduced. However, when the Kulubnarti pelves are compared to the Amerindians, it can be seen that they are usually smaller, and significantly so, in most dimensions (Table 3).

In summary, while the Kulubnarti pelves are typically female in shape, they are smaller than the comparative Amerindian samples as well as the modern American obstetric standards. Indeed, many are reduced
to dimensions considered pathological by modern clinical standards.

**DISCUSSION**

A small mesatipellic or brachypellic pelvis is most commonly observed in the Kulubnarti sample. Indeed the distribution of pelvic types is similar to that observed for modern North American females (Caldwell and Moloy, 1933; Thoms et al., 1939). The reduced size is of interest in the context of previous research on the Kulubnarti remains. For example, Hummert and Van Gerven (1983) and Moore et al. (1986) observed evidence for growth retardation. There is also abundant evidence for nutritional stress inferred from high frequencies of porotic hyperostosis (Van Gerven et al., 1981) and enamel hypoplasia (Van Gerven et al., 1988). The population also experienced extremely high infant mortality with a modal age at death of birth (Van Gerven et al., 1981).

Beyond the suggested relationship to growth and nutritional stress, the obstetric significance of the smaller Kulubnarti pelves is difficult to assess. The capacity of the female pelvis for childbearing is profoundly influenced by size and shape relative to that of the fetus. These factors often complement one another; a poorly shaped pelvis may be compensated for by large dimension, and a small pelvis by well-formed contours. Moreover, the force of labor is one of the most important factors influencing outcome. A small mesatipellic or brachypellic pelvis often occurs in women of small stature who, as a rule, have babies that are proportionately small. Labor in these women generally resolves in a spontaneous delivery, because of the relative amount of space in the pelvis. However, if any of the obstetric dimensions are reduced beyond the capacity of the fetus to adapt itself by means of favorable presentation, position, attitude, and/or cranial molding, difficulties occur in the form of protracted or arrested labor (Baird, 1969; Caldwell and Moloy, 1933; Friedman, 1978; Oxorn and Foote, 1980; Pritchard et al., 1985; Thoms, 1956; Thoms et al., 1939). Varying kinds and degrees of maternal-neonatal morbidity or mortality may then result.

That the Kulubnarti pelves are smaller than the contemporary North American standard does not in itself establish a high rate of obstetric difficulty. The Nubian females are shorter in stature with an average height of 62 inches (Hummert and Van Gerven, 1983). What may be of greater obstetric importance is the substantial number of the Kulubnarti pelves that are clinically classifiable as contracted. Of the 36 analyzed, 33% had moderate inlet contracture (<9.0 cm). For the moderately contracted the prognosis for successful delivery of a term size fetus is borderline, and for the severely contracted the prognosis is considered nearly hopeless (Pritchard et al., 1985). It is likely, of course, that the Nubian neonates were also of reduced size and while this may reduce obstetric complications, it increased the risk of neonatal morbidity and mortality. As previously discussed, the modal age at death at Kulubnarti is birth (Van Gerven et al., 1981). We suggest that fetopelvic disproportion combined with reduced neonatal size may have been important factors contributing to this high death rate.

Certainly, fetopelvic disproportion and obstetric tragedy existed in ancient Nubia as in modern populations. The possible breach delivery at Kulubnarti bears silent witness to this grim fact. It is possible that individuals S-224, R-85, and R-99, or others like them with markedly reduced pelvic dimensions, suffered untold reproductive morbidity and, perhaps, mortality.

**CONCLUSIONS**

The size and shape of the adult female pelvis reflects a complex history of heredity and environmental interactions. It has been noted in temperate, industrialized populations that women of greater socioeconomic means are generally healthier, taller, have roomier pelves, and better reproductive histories than those less fortunate (Baird, 1945, 1969; Thoms et al., 1939; Thoms, 1956). It cannot be assumed, however, that the same holds true for women living under different biocultural conditions, past or present (Tanner, 1978). For example, Gebbie (1981), in an excellent survey of fetopelvic disproportion in several populations of
sub-Saharan Africa, has linked undernutrition during the formative years to development of small non-pathological pelves and to subsequent widespread reproductive morbidity and mortality. Arriaza et al. (1988) have estimated that one in four females from an early agricultural period in Chile died of complications related to childbirth. While all of the affected females had normal pelves relative to modern obstetric standards, we would suggest that overall size and nutrition played some role in this high rate. On the other hand, Frisancho and colleagues (1973) and Stini (1972), studying undernourished South African populations, have observed that small maternal body size (and presumably small pelvic size) is associated with heightened reproductive success. On this basis, Stini concluded:

Since smaller infants are generally born by smaller mothers who have experienced a relatively smaller weight gain during pregnancy, the survival of such infants in areas of poor nutrition would add a genetic factor to the development and behavioral influences associated with reduced stature (Stini, 1972).

It is not within the scope of this paper to debate the issue of the adaptive advantages of small body size under such life circumstances. However, it is important to understand that regardless of one's position on the issue, the potential for maternal-neonatal morbidity and mortality due to fetopelvic disproportion and reduced neonatal birth weight remains (Wells, 1975; Wells and Hanke, 1975).

In conclusion, one can envision small body size as one biological response of this Medieval population to the meager, fluctuating resources of a harsh desert land (Hummert & Van Gerven, 1983). It is likely, however, that this response had associated biological costs in terms of obstetric-related morbidity and mortality.

ACKNOWLEDGMENT

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LITERATURE CITED


Stewart DB (1984b) The pelvis as a passageway. II. The